Impact Evaluation of 2009 Custom HVAC and 2008-2009 Custom CDA Installations

National Grid's Rhode Island Large Commercial & Industrial Evaluation

Prepared for: National Grid

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1. Introduction

This document summarizes the work performed by KEMA and SBW during 2010 and 2011 to quantify the actual energy and demand savings due to the installation of three Custom Heating, Ventilation and Air-Conditioning (HVAC) measures and two Custom Comprehensive Design Approach (CDA) projects installed through National Grid's Energy Initiative and Design*2000* energy efficiency programs in 2008 and 2009 in Rhode Island (RI). This report also summarizes the sampling and analysis procedures used for developing the population level results, which are based on the combined results of the Rhode Island sites and a concurrent study of National Grid Custom HVAC and CDA projects in Massachusetts.

1.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for a sample of three Rhode Island Custom HVAC projects and two Custom CDA projects through site-specific inspection, monitoring, and analysis, and to develop new realization rates for the Custom HVAC and CDA populations in Rhode Island. The results of the project studies are combined with the results from a concurrent study of National Grid Custom HVAC and CDA installations in Massachusetts to determine appropriate population level realization rates for the Custom HVAC and Custom CDA populations in Rhode Island..

This impact study consists of the following four tasks:

1. Develop Sample Design
2. Develop Site Measurement and Evaluation Plans
3. Data Gathering and Site Analysis
4. Report Writing and Follow-up
5. Analysis Procedures and Development of Population Results
6.

1.2 Scope

The scope of work of this impact evaluation covered the 2009 Custom HVAC end-use and the 2008 and 2009 Custom CDA program track. The Custom HVAC end-use includes high efficiency HVAC equipment, HVAC controls as part of Energy Management Systems (EMS), O&M and retro-commissioning HVAC measures, and building shell improvements that impact HVAC loads.

Custom CDA projects fall into one of two categories: Comprehensive Design (CD) and Comprehensive Chiller (CC). CD projects typically involve the new construction of a commercial, industrial or municipal building and include at least four energy conservation measures (ECMs) to achieve at least 20% electric energy savings compared to the code-compliant baseline. CC projects typically involve an existing facility and include the installation of a new chiller and multiple other ECMs to achieve at least 20% energy savings compared to the existing (pre-project) equipment and operation. Although these categories address slightly different customer markets, all projects typically involve a similar mix of measures and utilize whole building simulation tools to develop energy and demand reduction estimates.

Typical ECMs implemented through a CDA project include: building envelope upgrades, lighting fixtures and controls, cooling system upgrades and EMS controls, demand controlled ventilation (DCV) and enthalpy economizer controls, and variable frequency drives (VFD) on system fans and pumps.

This impact evaluation includes only measures which primarily reduce electricity consumption.

2. Description of Sampling Strategy

The primary focus of the sample design task was to examine various precision scenarios for the Custom HVAC and Custom CDA program tracks in Rhode Island. Design parameters for National Grid's Massachusetts Custom HVAC and Custom CDA program tracks were developed previously and are described in the final reports for the MA-LCIEC Projects 3[1] and 6A[2]. The study populations for National Grid's Rhode Island programs are summarized in Table 1.

Table 1: RI Population Statistics

RI Program	Projects	Gross kWh Savings	Average Savings	Minimum	Maximum	Standard Deviation	CV
Custom CDA	10	7,093,041	709,304	124,507	2,179,455	605,004	0.85
Custom HVAC	22	1,695,899	77,086	8,200	293,163	87,574	1.14
Total	32	8,788,940					

[1] Impact Evaluation of 2009 Custom HVAC Installations, prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council, by KEMA and DMI, June 2011.

[2] Impact Evaluation of 2008 and 2009 Custom CDA Installations, prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council, by KEMA and SBW, June 2011.

The initial design approach was to support the estimation of annual kWh savings realization rates for National Grid's programs in Rhode Island. While annual kWh savings was the primary variable of interest, National Grid is also interested in achieving accurate results for coincident summer peak demand (kW), in order to meet the ISO-NE guidelines for 80/10 precision for their overall portfolio of programs.

Sample designs and anticipated precisions for annual kWh and summer kW are presented in the following sections. The evaluation sample for this study was designed in consideration of the requirements for a 90% confidence level for energy (annual kWh) and an 80% confidence level for coincident peak summer demand (kW).

2.1 Annual kWh Sample Designs

KEMA presented several preliminary sample designs stratified by annual kWh for National Grid's Custom CDA and Custom HVAC programs in Rhode Island. The parameters considered in the sample design are the number of sample observations planned and the anticipated error ratio of the quantity being estimated which, in this case, is the realization rate for evaluated savings. The error ratio is a measure of the strength of the relationship between the known characteristic (i.e., tracking system savings) and the unknown population characteristic (i.e., evaluated savings). For Custom HVAC an error ratio of 0.6 was assumed based on the results of two recent evaluations done for National Grid. Similarly, the Custom CDA design used an error ratio of 0.2 based on a previous study.[3]

For both the CDA and HVAC end-use groups, various sample sizes were reviewed and designs were selected based on anticipated precisions and budget constraints. The final annual kWh design, which served as the basis for the sample selection for both studies, is shown in Table 2. The anticipated precisions for this design are shown in Table 3. While the individual results for Custom HVAC in Rhode Island were not expected to produce estimates with great precision, consideration was made for the possibility that they may be combined with Massachusetts results for determining an overall National Grid realization rate for this program.

Combining Rhode Island results with Massachusetts results from similar and concurrent studies was considered due to the high cost of conducting Rhode Island specific evaluations with large enough samples to produce statistically representative results and the fact that the National Grid's program design and delivery infrastructure is similar in both states subsidiaries.

[3] Sample Design and Impact Evaluation Analysis of the 2009 Custom Program, prepared for National Grid, by KEMA, July 2010.

The achieved precision levels for the state-level and aggregated results are presented later in Table 10, Table 11, Table 15, and Table 16 of this report.

Table 2: RI CDA & HVAC Sample Designs

RI Program	Stratum	Maximum Gross KWh Savings	Projects	Total Gross kWh Savings	Sample	Inclusion Probability
Custom CDA	1	836,080	7	2,739,103	1	0.1429
Custom CDA	2	2,179,455	3	4,353,938	1	0.3333
Custom HVAC	1	62,200	15	392,417	1	0.0667
Custom HVAC	2	214,428	4	522,544	1	0.2500
Custom HVAC	3	293,163	3	780,938	1	0.3333

Table 3: RI CDA & HVAC Anticipated Precisions for Annual KWh

RI Program	Projects	Total Gross Savings (kWh)	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Custom CDA	10	7,093,041	0.2	90%	2	±21.9%
Custom HVAC	22	1,695,899	0.6	90%	3	±52.8%
Total	32	8,788,940			5	±20.4%

2.2 Coincident Summer Peak Demand (kW) Sample Designs

Before deciding on a final sample design, it is useful to examine the estimated summer kW precision that could be achieved with a sample of this size. The error ratio for summer kW savings from the previous Custom CDA study was similar to that for annual kWh, so the same value of 0.2 was assumed for this calculation. For the Custom HVAC study, the error ratios for summer kW savings were significantly higher, so 1.2 was used to calculate anticipated precision here. Table 4 reports the anticipated precision for summer kW savings, based on a confidence level of 80%. Neither of the anticipated precision levels meets the target of 10%, but these programs are a small portion of the National Grid portfolio, so they were acceptable given the very small sample sizes.

Table 4: Anticipated Precision for Summer KW

RI Program	Projects	Summer KW Savings	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Custom CDA	10	2,411	0.2	80%	2	±17.1%
Custom HVAC	22	723	1.2	80%	3	±82.3%
Total	32	3,134			5	±23.1%

2.3 Final Samples

Based on these stratified designs, random samples of projects were selected from the tracking system data. Table 5 presents the list of three projects selected as the final sample for Custom HVAC. Table 6 presents the list of two projects selected as the final sample for Custom CDA. Note that projects that had not yet been fully commissioned at the time of the study were not considered for the evaluation. Also, one CDA site got replaced with a backup site in order to achieve a more balanced representation of the measures in the population of projects. KEMA evaluated all three of the Custom HVAC projects, while SBW evaluated both of the CDA projects.

Table 5: RI HVAC Final Sample Selection

Stratum	Project ID	Evaluator	Project Description
1	N541507	KEMA	Library, Convert constant air volume boxes to variable air volume boxes
2	N541423	KEMA	Airport, Updating EMS controls on HVAC and lighting equipment
3	N533129	KEMA	University, Install new high efficiency chillers

Table 6: RI CDA Final Sample Selection

Stratum	Project ID	Evaluator	Project Description
1	N537877	SBW	School, Six ECMs affecting HVAC and Lighting systems
2	N527021	SBW	Office Building, Ten ECMs affecting HVAC, Lighting and Envelope

3. Description of Methodology

3.1 Measurement and Evaluation Plans

Following the final sample selection of 2009 Custom HVAC and 2008-2009 CDA applications and prior to beginning any site visits, KEMA and SBW developed detailed measurement and evaluation plans for each of the five applications. The plans outlined on-site methods, strategies, monitoring equipment placement, calibration and analysis issues. National Grid provided comments and edits to clarify and improve the plans prior to them being finalized.

Evaluators utilized the savings analysis methodologies from the Technical Assistance (TA) Study whenever possible. There were two instances where the TA methodology was found to be incorrect or inappropriate, and evaluators performed an analysis more appropriate to the measure being evaluated. Adjustments to savings methodologies were presented and agreed to in the measurement and evaluation plans.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives of the study were met. Each site visit culminated in an independent engineering assessment of the actual (e.g. as observed and monitored) annual energy, on-peak energy, coincident summer peak demand, and coincident winter peak demand savings associated with each project.

3.2 Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, short-term metering of usage and EMS trends. At each site, KEMA or SBW performed a facility walk-through that focused on verifying the post-retrofit or installed conditions of each energy conservation measure (ECM). Some of the facilities utilized EMS controls which were either part of the application itself or controlled equipment that was included in the application. Evaluators viewed EMS screens to verify schedules and operating parameters where applicable. Instrumentation such as power recorders, Time-Of-Use (TOU) lighting loggers, TOU current loggers, and temperature loggers were installed to monitor the usage of the installed HVAC equipment and associated affected spaces. EMS trends were also collected, when available.

Savings analyses were used to estimate hourly energy use and diversified coincident peak demand. A typical meteorological year (TMY3) dataset of ambient temperatures closest to each facility was used for all temperature sensitive calculations. Each site report details the specific analysis methods used for each project including algorithms, assumptions and calibration methods where applicable. For CDA sites, the analyses were done using calibrated, whole building simulations in Trane TRACE. For HVAC sites, both spreadsheet analyses and eQUEST building simulations were used to estimate savings.

KEMA and SBW submitted draft site reports to National Grid upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix A: Site Reports. This executive summary provides a concise overview of the evaluation methods and findings.

3.3 Analysis Procedures

In order to aggregate the individual site results from the Custom CDA and Custom HVAC samples, KEMA applied the model-assisted stratified ratio estimation methodology.[4,5] The key parameter of interest is the population realization rate, i.e., the ratio of the evaluated savings for all population projects divided by the tracking estimates of savings for all population projects. This rate is estimated for the Rhode Island populations only, as well as for National Grid's combined populations of Rhode Island and Massachusetts. Of course, the population realization

[4] The California Evaluation Framework, prepared for Southern California Edison Company and the California Public Utility Commission, by the TecMarket Works Framework Team, June 2005, Chapters 12-13.

[5] Model Assisted Survey Sampling, C. E. Sarndal, B. Swensson, and J. Wretman, Springer, 1992.

rate is unknown, but it can be estimated by evaluating the savings in a sample of projects. The sample realization rate is the ratio between the weighted sum of the evaluated savings for the sample projects divided by the weighted sum of the tracking estimates of savings for the same projects. The statistical precisions and error ratios are calculated for each level of aggregation.

The results presented in the following section include realization rates (and associated precision levels) for annual kWh, % kWh on-peak and demand (kW) savings during winter and summer on-peak periods, as defined by the ISO-NE Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.
- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for portfolios participating in the FCM. For all kWh realization rates, the standard 90% confidence level is used.

4. Custom HVAC Results

Evaluated savings data for the Rhode Island HVAC sample points were analyzed to develop Rhode Island realization rates, and then combined with National Grid Massachusetts results (previously reported for the MA-LCIEC Project 3 Impact Evaluation) to represent overall National Grid results for the Custom HVAC end-use.

In preparation for analyzing the evaluation results collected for the Custom HVAC sample points, the original 2009 population distribution was used to calculate case weights for each observation in the Rhode Island sample. These weights reflect the number of projects that each sample point represents and allow for the aggregation of results across strata. The case weights for this study are shown in the last column in Table 7.

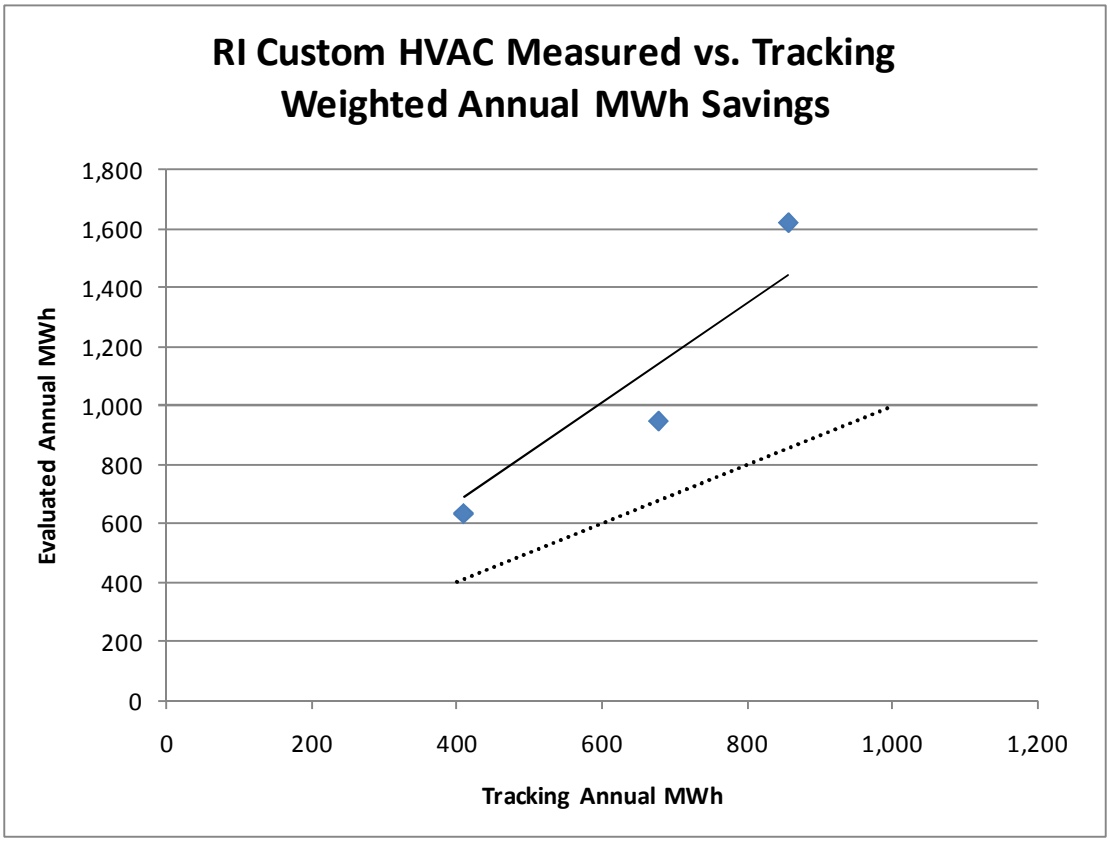
Table 7: RI Custom HVAC Case Weights

Stratum	Total Applications	Total Annual KWh	Applications in Sample	Case Weight
1	15	392,417	1	15.00
2	4	522,544	1	4.00
3	3	780,938	1	3.00

4.1 Major Findings and Observable Trends

Figure 1 presents a scatter plot of evaluation savings for the three Rhode Island sample points. Each point has been weighted by the number of population projects that it represents. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the realization rate, and can be seen to be greater than one. Although there are only three points, it appears that they are fairly close to the estimated line, which suggests that the actual error ratio may be lower than the 0.6 which was assumed for this study.

Figure 1: Scatter Plot of RI HVAC Evaluation Results for Annual KWh Savings



4.2 Presentation of Results

Table 8 presents a summary of the site level results for this impact evaluation.

Table 8: RI HVAC Detailed Site Results

Stratum	Project ID	Tracking Estimated Savings				Evaluation Savings			
			On-Peak	Peak Coinc.			On-Peak	Peak Coinc.	
		kWh/yr	%	Sum. kW	Wint. kW	kWh/yr	%	Sum. kW	Wint. kW
1	N541507	27,364	0%	2.7	5.2	42,419	76%	17.2	2.4
2	N541423	214,428	41%	26.7	34.1	404,653	21%	21.9	7.2
3	N533129	226,312	75%	78.7	0.0	316,180	52%	105.5	0.0

Table 9 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings for the Custom HVAC sites. The site energy savings realization rates ranged from a low of 140% for the stratum 3 site to a high of 189% for the stratum 2 site. Note that some of the ratios are "N/A" for the on-peak % and peak coincident demand reductions because the tracking estimates were zero for some of these values.

Table 9: RI HVAC Primary Site Discrepancies

Stratum	Project ID	Ratio Evaluated/Tracking				Primary Reasons For Discrepancies
			On-Peak	Peak Coinc.		
		kWh/yr	%	Sum. kW	Wint. kW	
1	N541507	155%	N/A	628%	46%	Savings increased because tracking estimates did not include cooling savings or reheat pump savings.
2	N541423	189%	50%	82%	21%	Savings increased because tracking estimates did not include all measures and underestimated the demand controlled ventilation savings.
3	N533129	140%	70%	134%	N/A	Savings increased because tracking underestimated the night and weekend cooling loads.

The site-level evaluation results for Rhode Island were aggregated using stratified ratio estimation. The Rhode Island and Massachusetts realization rates were then applied to their respective total tracking savings to estimate each state's total evaluated savings. The National Grid combined realization rate is the ratio of the total evaluated savings to the total tracking savings, each of which is calculated by summing across the two states. Table 10 summarizes the state-level results and Table 11 the aggregated company results. Since the design criteria for the demand realization rates were different than those for the annual kWh (80% vs. 90%

confidence levels), the precisions are reported only in the appropriate rows in these tables. An 'na' in a cell indicates that the confidence level shown is not applicable.

Table 10: Summary of State-Level Custom HVAC Results

State	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Rhode Island					
Total Tracking Savings	1,695,899	778,138	45.9%	723	442
Total Measured Savings	2,790,141	1,413,084	50.6%	1,248	134
Realization Rate	164.5%	181.6%	110.4%	172.7%	30.2%
Relative Precision at 90% Confidence	±11.8%	±69.3%	-	na	na
Error Bound at 90% Confidence	328,685	979,683	-	na	na
Relative Precision at 80% Confidence	na	na	-	±41.3%	±31.9%
Error Bound at 80% Confidence	na	na	-	516	43
Error Ratio	0.14	0.81	-	0.63	0.47
Massachusetts					
Total Tracking Savings	9,281,937	4,490,015	48.4%	1,489	1,001
Total Measured Savings	9,330,597	4,834,262	51.8%	1,245	825
Realization Rate	100.5%	107.7%	107.1%	83.6%	82.4%
Relative Precision at 90% Confidence	±10.7%	±10.8%	-	na	na
Error Bound at 90% Confidence	997,345	522,332	-	na	na
Relative Precision at 80% Confidence	na	na	-	±12.7%	±27.1%
Error Bound at 80% Confidence	na	na	-	158	224
Error Ratio	0.38	0.38	-	0.64	1.26

Table 11: Summary of Overall National Grid HVAC Results

Overall	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Total Tracking Savings	10,977,836	5,268,153	48.0%	2,212	1,444
Total Measured Savings	12,120,737	6,247,346	51.5%	2,493	959
Realization Rate	110.4%	118.6%	107.4%	112.7%	66.4%
Relative Precision at 90% Confidence	±8.7%	±17.8%	-	na	na
Error Bound at 90% Confidence	1,050,110	1,110,230	-	na	na
Relative Precision at 80% Confidence	na	na	-	±21.7%	±23.8%
Error Bound at 80% Confidence	na	na	-	540	228
Error Ratio	0.33	0.48	-	0.63	1.15

From the state-level results, we can observe that the Rhode Island realization rates are higher than those estimated for Massachusetts for all but the On-peak winter kW, which is significantly lower. At 11.8%, the precision on the Annual KWh estimate is good, and at 0.14, the error ratio is significantly below the 0.4 that was assumed during planning. The demand realization rates also achieved slightly better precisions than had been anticipated. Both on its own, and when combined with Massachusetts, all Rhode Island The realization rates are greater than 100% for all savings parameters except On-Peak Winter kW for both the Rhode Island population alone and for the combined Rhode Island and Massachusetts population.

The results of this study may be compared to other impact evaluations that National Grid has conducted previously. At 110.4% for annual kWh and 112.7% for summer kW, these new

realization rates indicate a significant improvement over the 2005-2006 population results which were 81.1% and 72.2%, respectively[6].

4.3 Implications for Future Studies

The results of this analysis can be used to inform future sample designs. During this study design, an error ratio of 0.6 was assumed for annual kWh savings and 1.2 was assumed for summer kW, based previous evaluation experience with National Grid. These were chosen to be conservative. The actual overall error ratios were significantly lower: the annual kWh error ratio was 0.33 and the summer kW error ratio was 0.63 for the overall National Grid population. Future sample plans may want to use 0.4 and 0.7 for annual kWh and summer kW respectively to ensure precise results.

4.4 Conclusions and Recommendations

Overall, the Custom HVAC program appears to be successfully providing energy and summer demand savings in Rhode Island. Only the estimates for winter demand savings were found to be lower than predicted for both sites that had winter kW tracking values. The following recommendations refer only to National Grid's Rhode Island sites. Additional recommendations, based on National Grid's Massachusetts sites, are available in the concurrent Massachusetts Custom HVAC impact evaluation referenced previously.

Review tracking calculation methodologies. Tracking calculation methodologies ranged from building simulations to single line calculations. Performance contractor proprietary software was also used for tracking estimates in a number of cases. Bin analyses, single line calculations, and proprietary software sometimes calculate on-peak energy savings and winter and summer peak demand savings using weighted averages or non-defined default multipliers. These different approaches and non-uniform averages and multipliers sometimes result in over or underestimation of peak savings values. Even though a TA analysis may apply the correct peak hours, these other undefined factors can sometimes contribute to the savings variances. It is recommended that evaluation calculations be performed with 8,760 hours spreadsheets. The exception is for eQUEST and DOE2 simulations which can be recreated with those programs. The use of 8,760 hour calculations provides the ability to calculate performance

[6] Sample Design and Impact Evaluation Analysis of the 2009 Custom Program, prepared for National Grid, by KEMA, July 2010, Table 17.

(baseline/existing and installed cases) to the unique weather or load profile for each hour. The use of TMY3 weather data as the standard in the hourly calculations provides the most current weather data for annualizing savings, and should be used for all savings calculations.

Consider all secondary sources of energy savings/penalties. It is recommended that all secondary sources of savings and/or penalties be considered. The measure analyzed at one site involved a reduction in airflow due to the installation of variable air volume boxes. The tracking study calculated fan savings, but did not consider cooling savings, or reheat pumping savings associated with the resulting reduction in airflow.

5. Custom CDA Results

Evaluated savings data for the Rhode Island CDA sample points were analyzed to develop Rhode Island specific realization rates, and then combined with National Grid Massachusetts results (previously reported in the MA-LCIEC Project 6A Impact Evaluation) to represent overall National Grid results for the Custom CDA end-use.

In preparation for analyzing the evaluation results collected for the Custom CDA sample points, the original 2008-2009 population distribution was used to calculate case weights for each observation in the Rhode Island sample. These weights reflect the number of projects that each sample point represents and allow for the aggregation of results across strata. The case weights for this study are shown in the last column in Table 12.

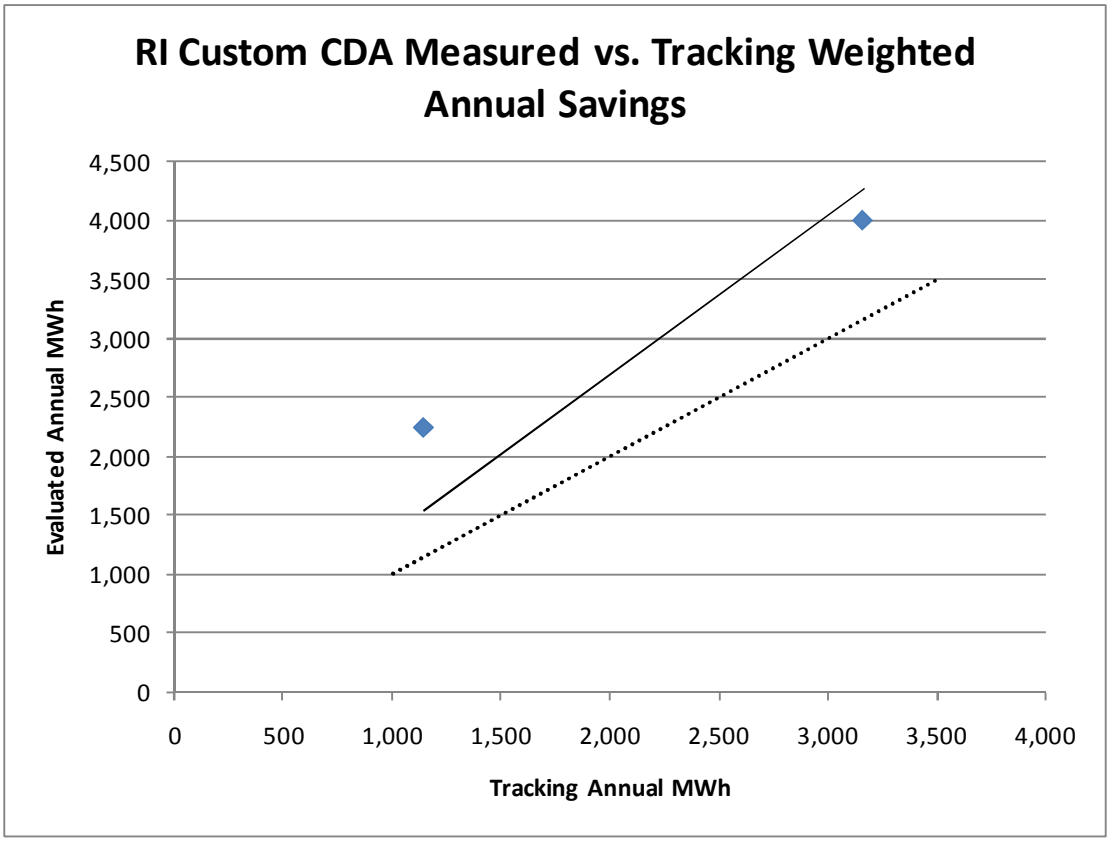
Table 12: RI Custom CDA Case Weights

Stratum	Total Applications	Total Annual KWh	Applications in Sample	Case Weight
1	7	2,739,103	1	7.00
2	3	4,353,938	1	3.00

5.1 Major Findings and Observable Trends

Figure 2 presents a scatter plot of evaluation savings for the two Rhode Island sample points. Each point has been weighted by the number of population projects that it represents. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the realization rate, and can be seen to be greater than one. Based on the limited number of data points, it appears that they are fairly close to the estimated line, suggesting that the error ratio is reasonably low. This confirms that the 0.2 error ratio used for planning this study was appropriate.

Figure 2: Scatter Plot of Evaluation Results for RI CDA Annual KWh Savings



5.2 Presentation of Results

Table 13 presents a summary of the site level results for this impact evaluation.

Table 13: RI CDA Detailed Site Results

		Tracking Estimated Savings				Evaluation Savings			
			On-	Peak Coinc.			On-	Peak Coinc.	
Stratum	Project ID	kWh/yr	Peak %	Sum. kW	Wint. kW	kWh/yr	Peak %	Sum. kW	Wint. kW
1	537877	163,838	96%	30.3	89.0	321,102	82%	78.6	32.6
2	527021	1,054,634	66%	626.6	358.0	1,335,432	75%	557.0	183.0

Table 14 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings for the Custom CDA sites. The site energy savings realization rates ranged from a low of 127% for the stratum 2 site to a high of 196% for the stratum 1 site.

Table 14: RI CDA Primary Site Discrepancies

Stratum	Project ID	Ratio Evaluated/Tracking kWh/yr	On-Peak %	Peak Coinc. Sum. kW	Peak Coinc. Wint. kW	Primary Reasons for Discrepancies
1	537877	196%	85%	259%	37%	Increase in savings because tracking savings conservatively underestimated savings for partially installed measures, and installed lighting power density was significantly lower than proposed.
2	527021	127%	114%	89%	51%	Increase in savings due to installed lighting power density that was significantly lower than proposed, and incorrect TA modeling assumptions and improper HVAC modeling approach.

The site-level evaluation results for Rhode Island were aggregated using stratified ratio estimation. Rhode Island and Massachusetts realization rates were then applied to their respective total tracking savings to estimate each state's total evaluated savings. The National Grid combined realization rate is the ratio of the total evaluated savings to the total tracking savings, each of which is calculated by summing across the two states. Table 15 summarizes the state-level results and Table 16 the aggregated company results. Since the design criteria for the demand realization rates were different than those for the annual kWh (80% vs. 90% confidence levels), the precisions are reported only in the appropriate rows in these tables. A 'na' in a cell indicates that the confidence level shown is not applicable.

Table 15: Summary of State-Level Custom CDA Results

State	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Rhode Island					
Total Tracking Savings	7,093,041	4,309,530	60.8%	2,411	1,456
Total Measured Savings	10,290,498	6,550,910	63.7%	2,560	667
Realization Rate	145.1%	152.0%	104.8%	106.2%	45.8%
Relative Precision at 90% Confidence	±19.0%	±7.1%	-	na	na
Error Bound at 90% Confidence	1,950,805	465,136	-	na	na
Relative Precision at 80% Confidence	na	na	-	±23.2%	±11.6%
Error Bound at 80% Confidence	na	na	-	593	78
Error Ratio	0.20	0.07	-	0.31	0.15
Massachusetts					
Total Tracking Savings	8,043,660	4,933,371	61.3%	2,577	1,165
Total Measured Savings	7,818,930	4,899,861	62.7%	1,650	639
Realization Rate	97.2%	99.3%	102.2%	64.1%	54.8%
Relative Precision at 90% Confidence	±25.4%	±27.5%	-	na	na
Error Bound at 90% Confidence	1,986,378	1,345,888	-	na	na
Relative Precision at 80% Confidence	na	na	-	±32.3%	±15.1%
Error Bound at 80% Confidence	na	na	-	533	96
Error Ratio	0.30	0.33	-	0.49	0.22

Table 16: Summary of Overall National Grid CDA Results

Overall	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Total Tracking Savings	15,136,701	9,242,901	61.1%	4,988	2,621
Total Measured Savings	18,109,428	11,450,771	63.2%	4,211	1,306
Realization Rate	119.6%	123.9%	103.6%	84.4%	49.8%
Relative Precision at 90% Confidence	±15.4%	±12.4%	-	na	na
Error Bound at 90% Confidence	2,784,122	1,423,996	-	na	na
Relative Precision at 80% Confidence	na	na	-	±18.9%	±9.5%
Error Bound at 80% Confidence	na	na	-	797	124
Error Ratio	0.24	0.18	-	0.38	0.19

The state-level results indicate that the Rhode Island realization rates are higher than those estimated for Massachusetts for all but the On-peak winter kW, which is slightly lower. Considering that there were only two sites in the sample, the precision is reasonably good. The Rhode Island error ratio for annual kWh is 0.2, which is exactly what was assumed. The error ratio for summer kW, at 0.31, is only slightly higher than the 0.2 that was used for planning. All Rhode Island realization rates, except for On-peak winter kW are greater than 100%. When combined with Massachusetts, only the kWh realization rates exceed 100%. Although the realization rates decrease by combining the Rhode Island results with National Grid's Massachusetts results, the relative precision is improved for both the energy and demand savings parameters.

The results of this study may be compared to other impact evaluations that National Grid has conducted previously. At 119.6% for annual kWh and 84.4% for summer kW, these new realization rates indicate a significant improvement over the 2006 results which were 96.5% and 79.3%, respectively.[7]

5.3 Implications for Future Studies

The results of this analysis can be used to inform future sample designs. During this study design, and error ratio of 0.2 was assumed for both annual kWh savings and summer kW, based on previous evaluation experience with National Grid. The actual overall error ratios were slightly higher: the annual kWh error ratio was 0.24 and the summer kW error ratio was 0.38. Future sample plans may want to use 0.3 for annual kWh and 0.4 for summer kW to ensure precise results.

5.4 Conclusions and Recommendations

Overall, the Custom CDA program appears to be successfully providing energy and demand savings in Rhode Island. Winter demand savings estimates were found to be lower than predicted for both sites. The following recommendation refers only to National Grid's Rhode Island sites. Additional recommendations, based on National Grid's Massachusetts sites, are available in the concurrent Massachusetts Custom CDA impact evaluation referenced previously.

Allow some time for sampling some sites. It is recommended that some sites may benefit from delaying evaluation until they are more "dialed in" to their new systems. Similar to avoiding evaluating sites that have not yet been commissioned, there are some sites that take a bit more time to become fully functional. In one case, evaluators were confronted with having to make assumptions in "gray" areas. Balancing that against gathering metered data for a building that is still in flux, might make it more beneficial to delay evaluation of these types of projects. If it can be identified early on that a building is still changing, these are the cases that might benefit from this strategy.

[7] Sample Design and Impact Evaluation Analysis of the 2009 Custom Program, prepared for National Grid, by KEMA, July 2010, Table 17.

Appendix A: Site Reports